Clustering
In Alpha Conjugate Nuclei

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Outline

- Experimental Setup
- Clusterization of alpha conjugate nuclei
  - Alpha like multiplicities
  - Origin of alpha particles from different breakup channels
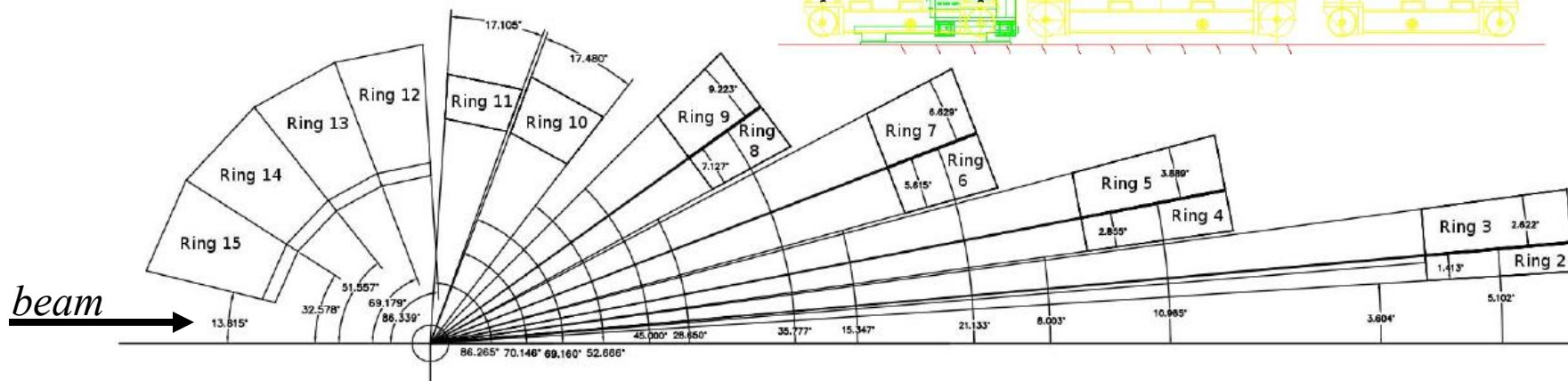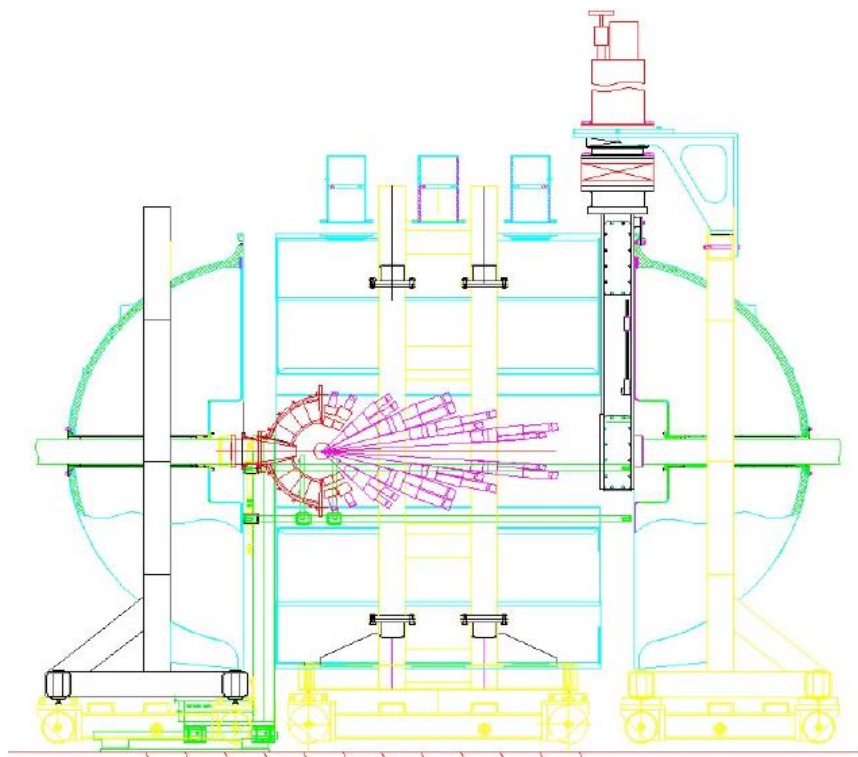 - Hierarchy effcect
- Summary

| Beam Energy: | 35 MeV/u | 35 MeV/u |
| Reactions: | ^{40}Ca + ^{40}Ca, ^{12}C, ^{181}Ta | ^{28}Si + ^{28}Si, ^{12}C, ^{181}Ta |

NIMROD

- 14 Concentric Rings
- 3.6-167 degrees
- Silicon Coverage
- Neutron Ball

S. Wuenschel et al., Nucl. Instrum. Methods. A604, 578–583 (2009).

Alpha clustering in nuclei

- **Ikeda diagram** (K. Ikeda, N. Takigawa, and H. Horiuchi, Prog. Theor. Phys. Suppl. Extra Number, 464, 1968.)
- Clusterization of low density nuclear matter in collisions of alpha conjugate nuclei
- Role of clusterization in dynamics and disassembly.

Estimated limit N = 10α for self-conjugate nuclei(Yamada PRC 69, 024309)
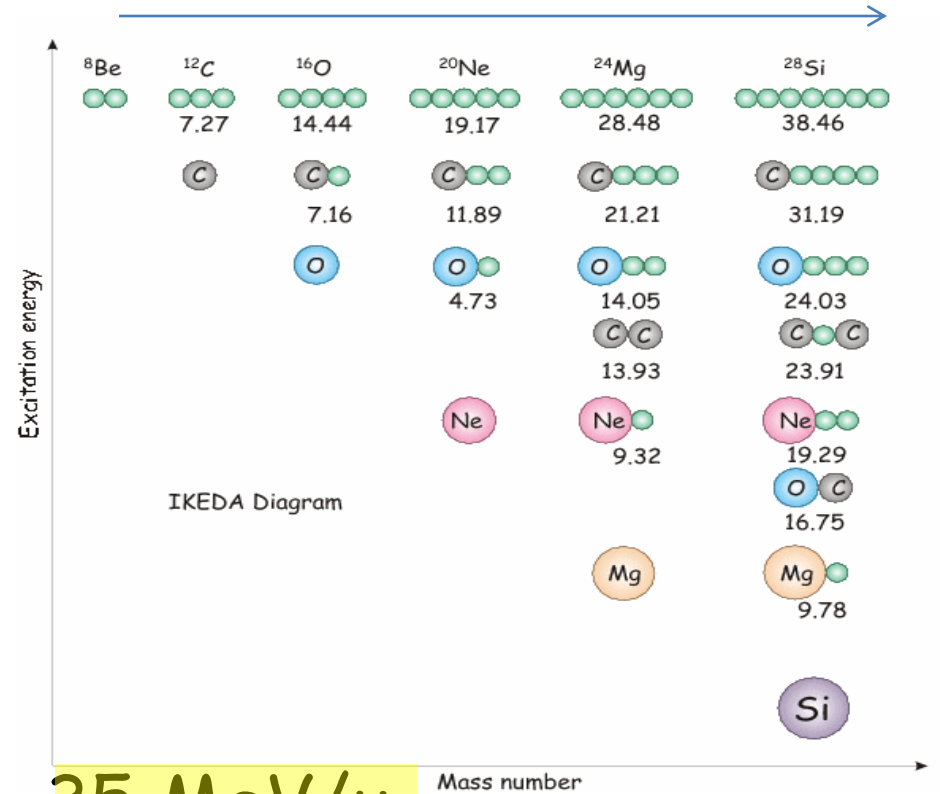
Data Taken

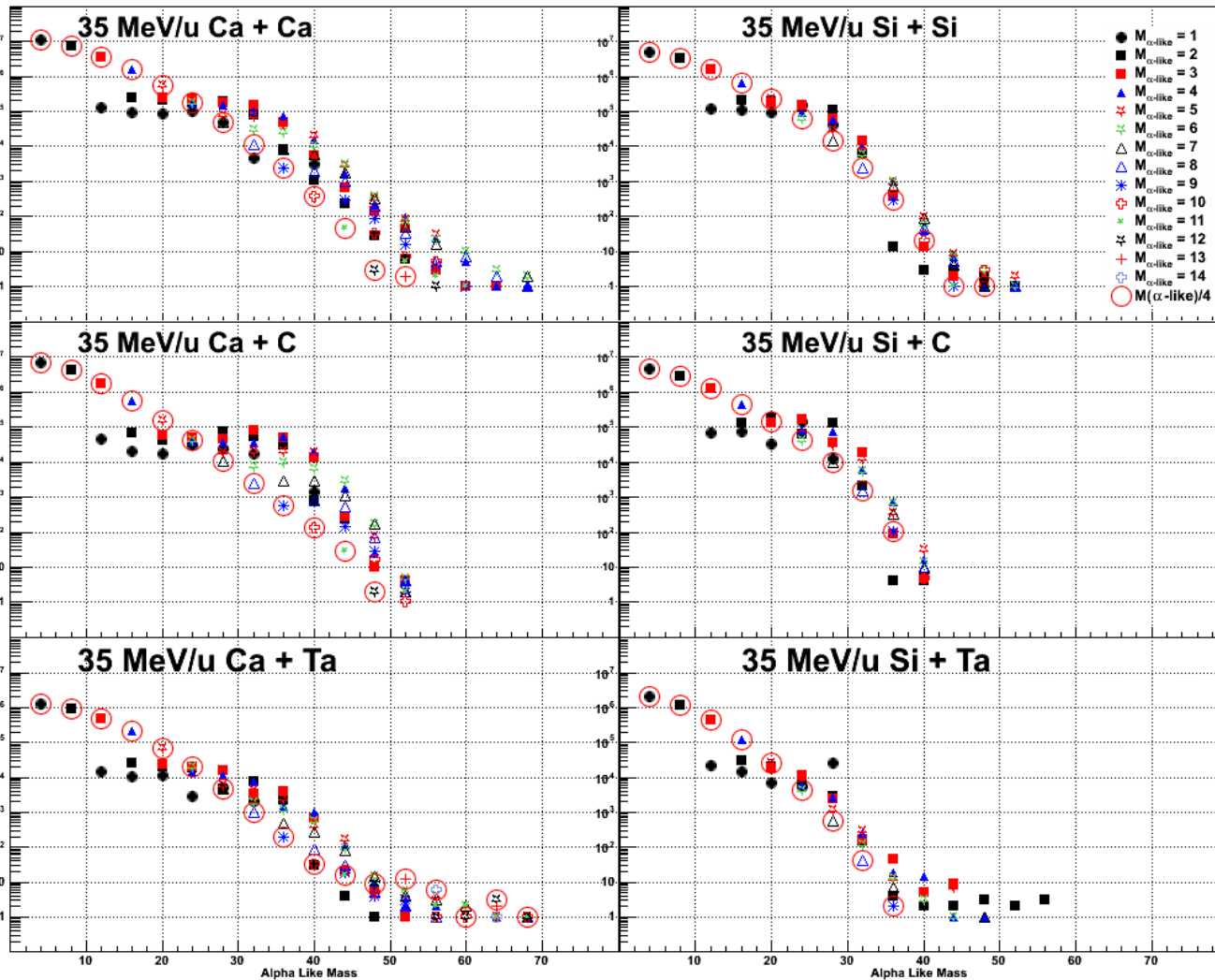| $^{40}Ca + {}^{40}Ca$	$^{28}Si + {}^{40}Ca$
$^{40}Ca + {}^{28}Si$	$^{28}Si + {}^{28}Si$
$^{40}Ca + {}^{12}C$	$^{28}Si + {}^{12}C$
$^{40}Ca + {}^{180}Ta$	$^{28}Si + {}^{180}Ta$

10, 25, 35 MeV/u

Focus on 35 MeV/u highlighted systems for current analysis

Alpha-like multiplicities

- Large number of events with significant alpha conjugate mass for all systems
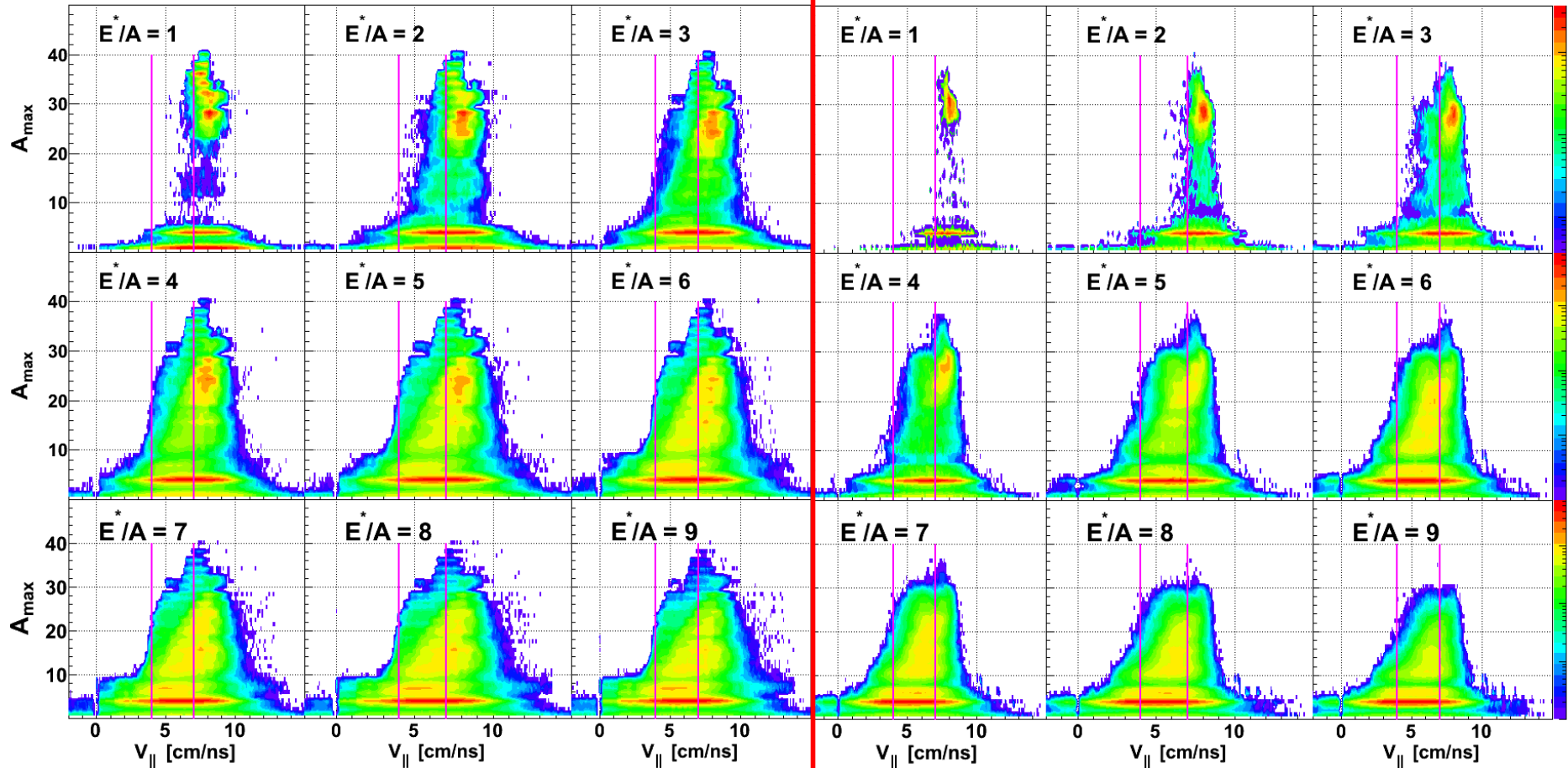
$V_{parallel}$ vs A_{max}

$$E^* = \sum_{i=1}^{M} K_{cp}(i) + M_n \langle K_n \rangle - Q$$

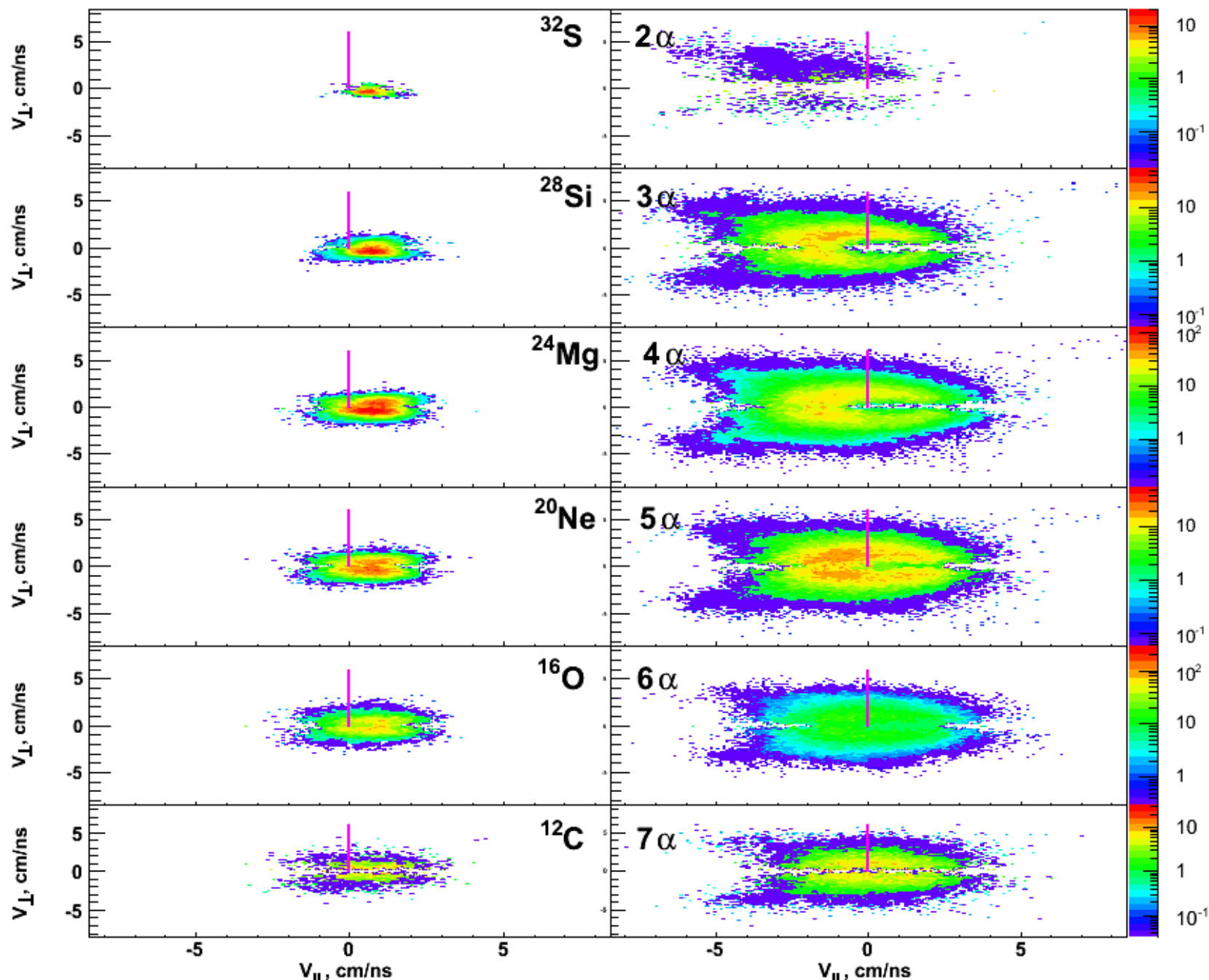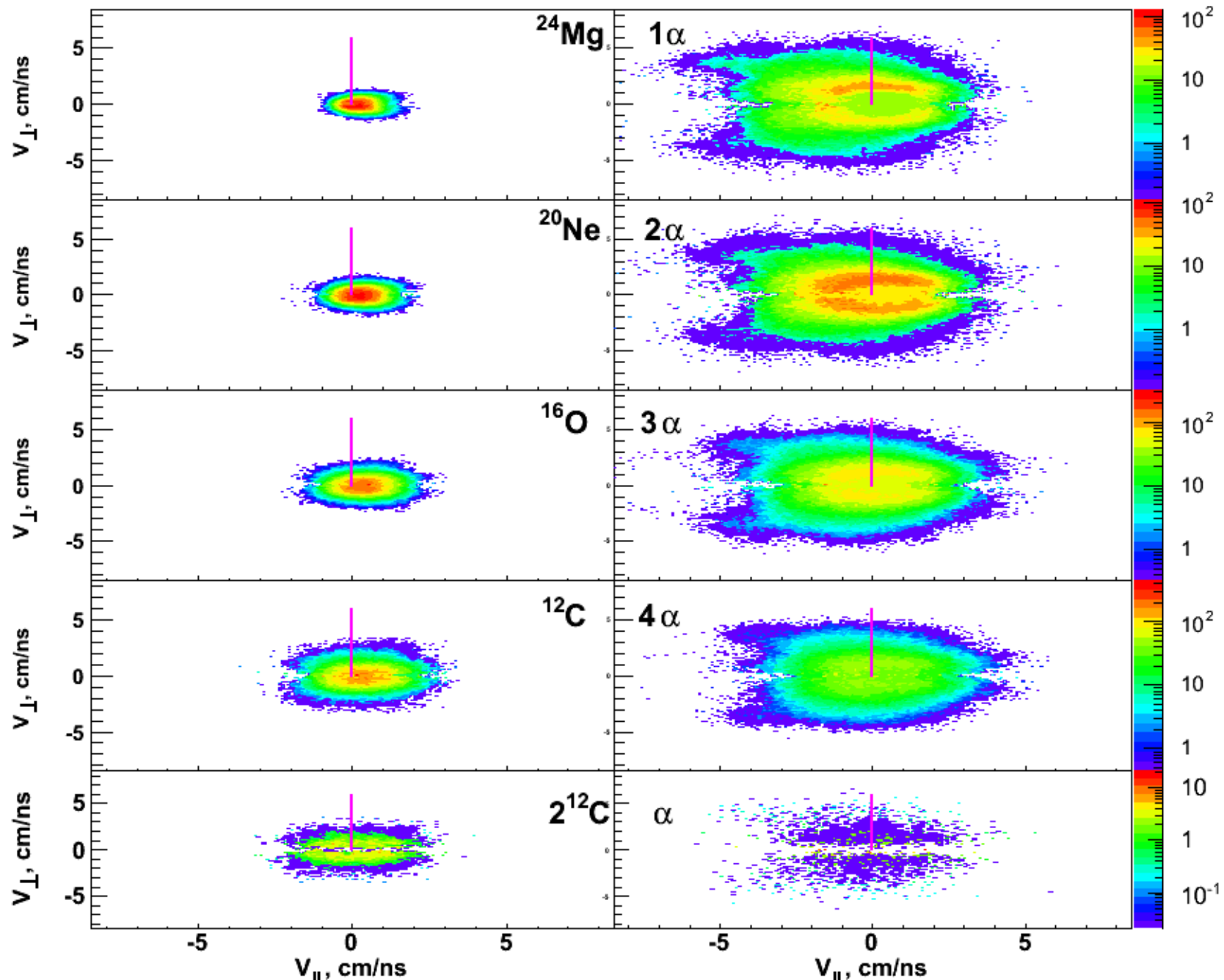- Observe mostly PLF near beam velocity for low E*
- More neck (4-7 cm/ns) emission of α-like fragments with increasing E*

35 MeV/u Ca + Ca alphaLikeMass = 40

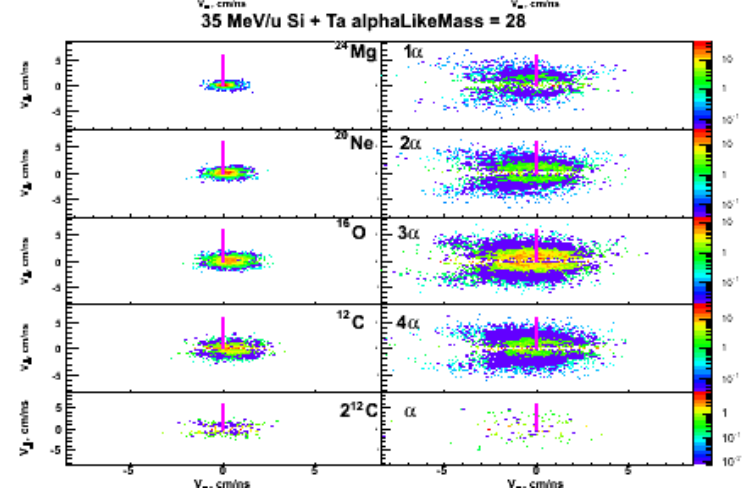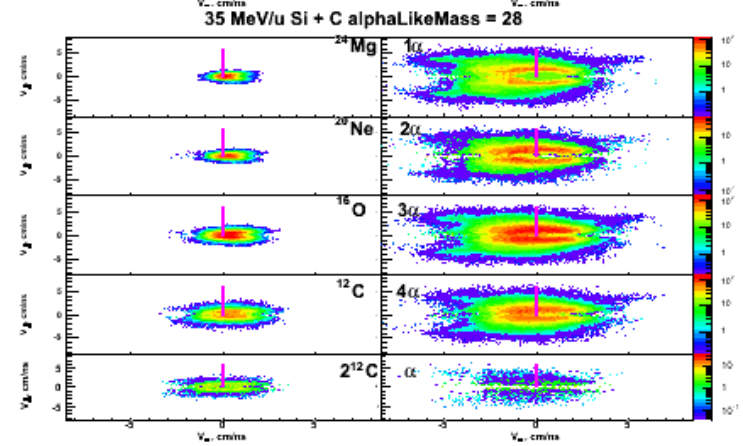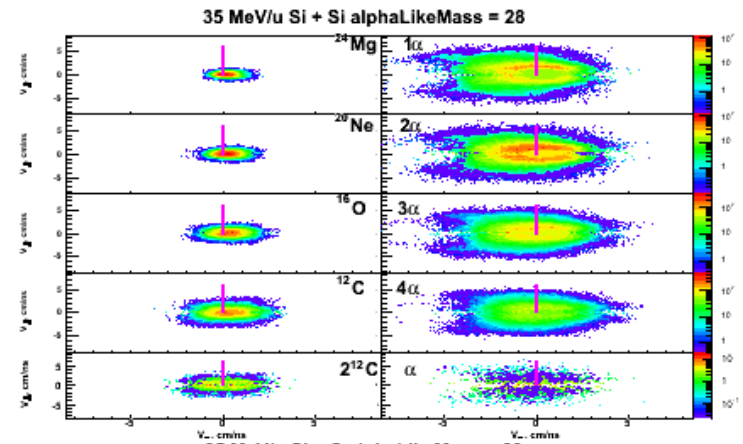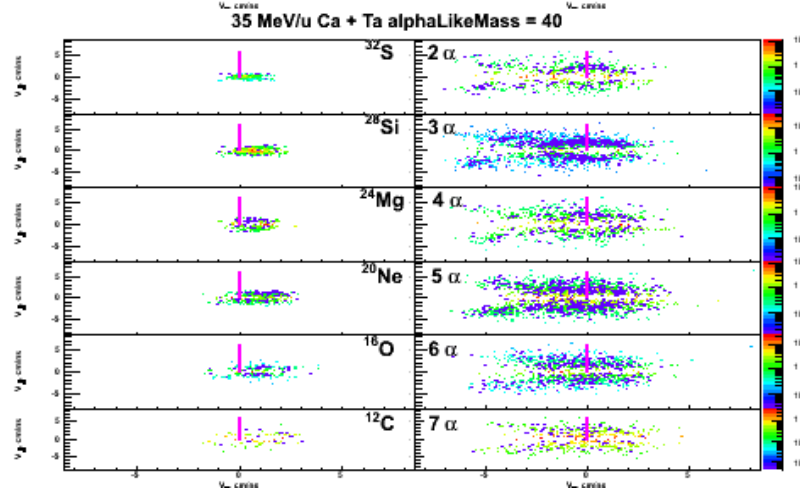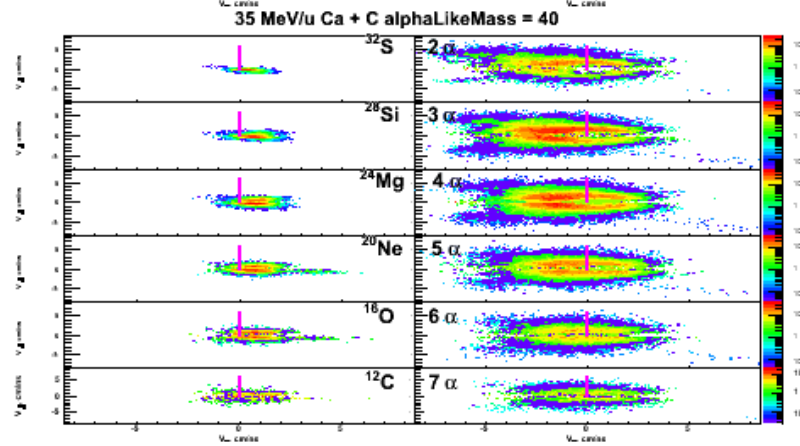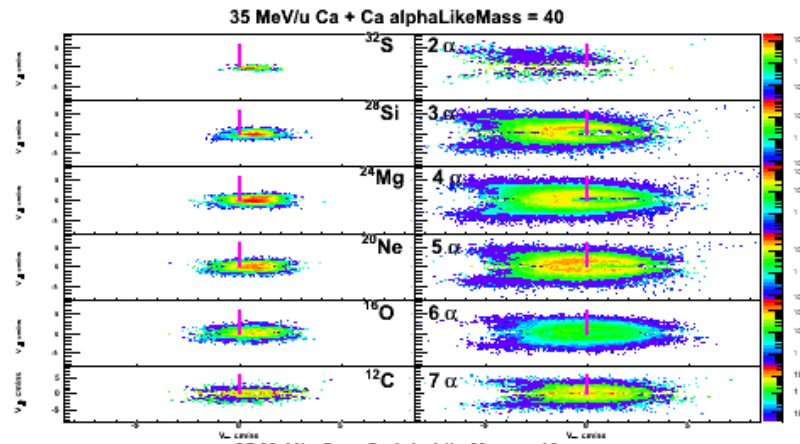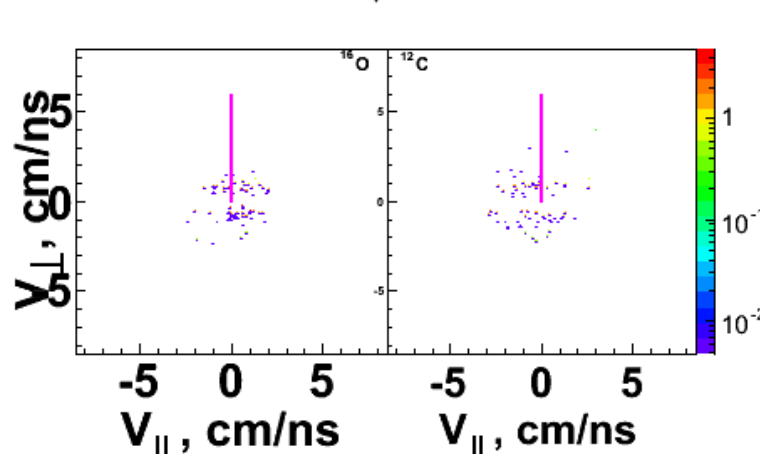# 35 MeV/u Si + Si alphaLikeMass = 28

Source Frame study of Origin of clusters

Source Frame Origin of clusters (continued)
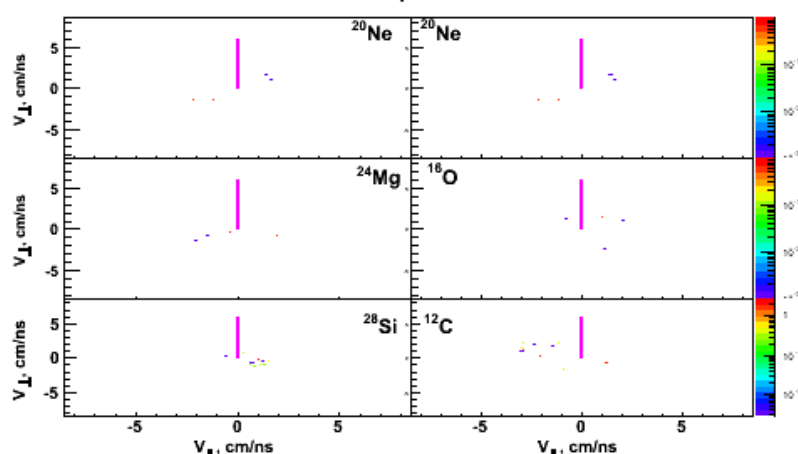
Hierarchy Effect

- J. Colin et al., Phys. Rev. C **67**, 064603 (2003)
- Ranking in charge induces a ranking in the parallel velocity
- Heaviest fragment is the fastest;
- Not consistent with the decay of fully equilibrated nucleus
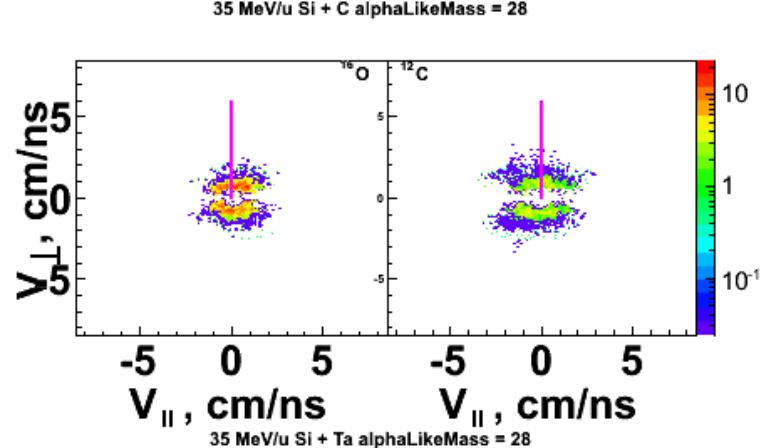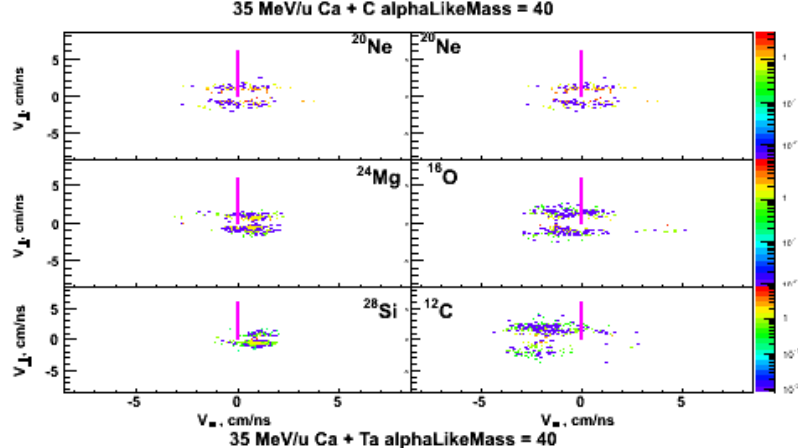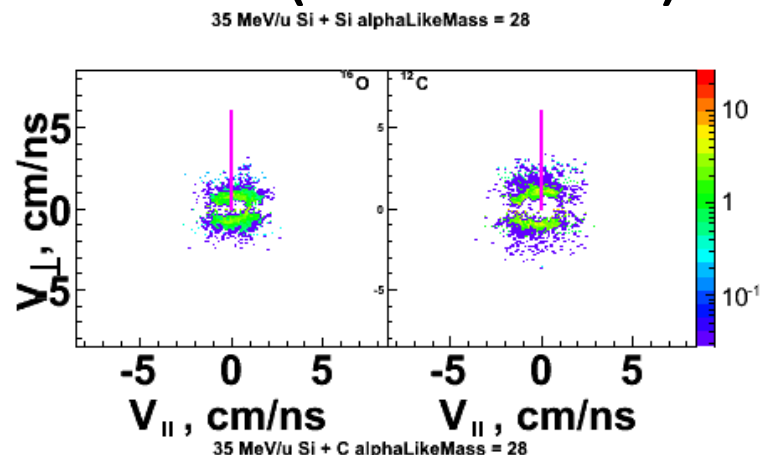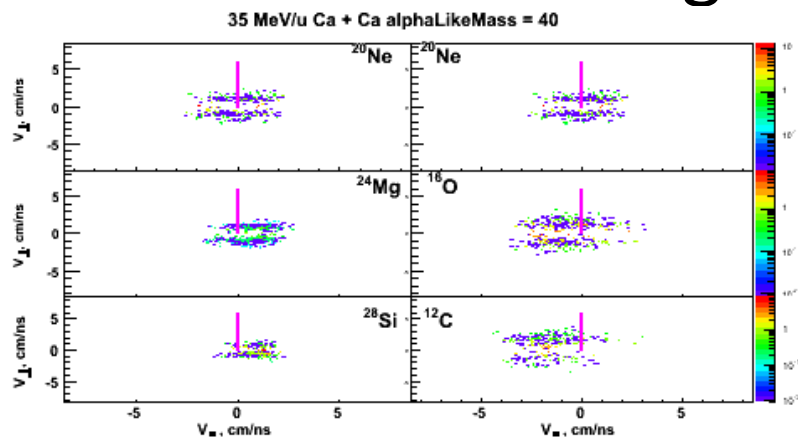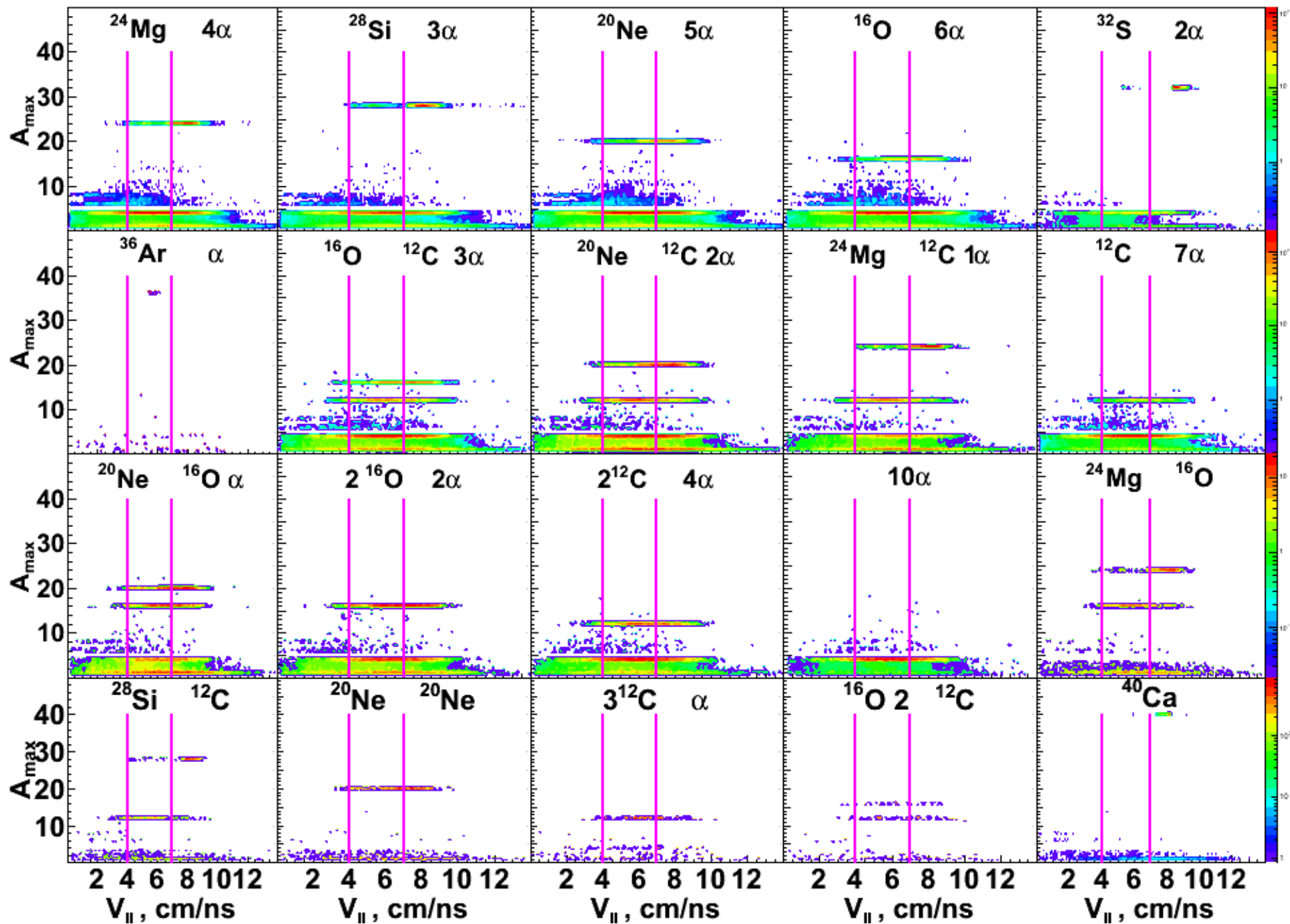
35 MeV/u Ca + Ca alphaLikeMass = 40

35 MeV/u Si + Si alphaLikeMass = 28

^{24}Mg 1α | ^{20}Ne 2α | ^{16}O 3α | ^{12}C 4α

7α | ^{16}O ^{12}C | 2^{12}C α | ^{28}Si

A_{max}

$V_{\parallel}$, cm/ns

35 MeV/u Ca + Ca alphaLikeMass = 40
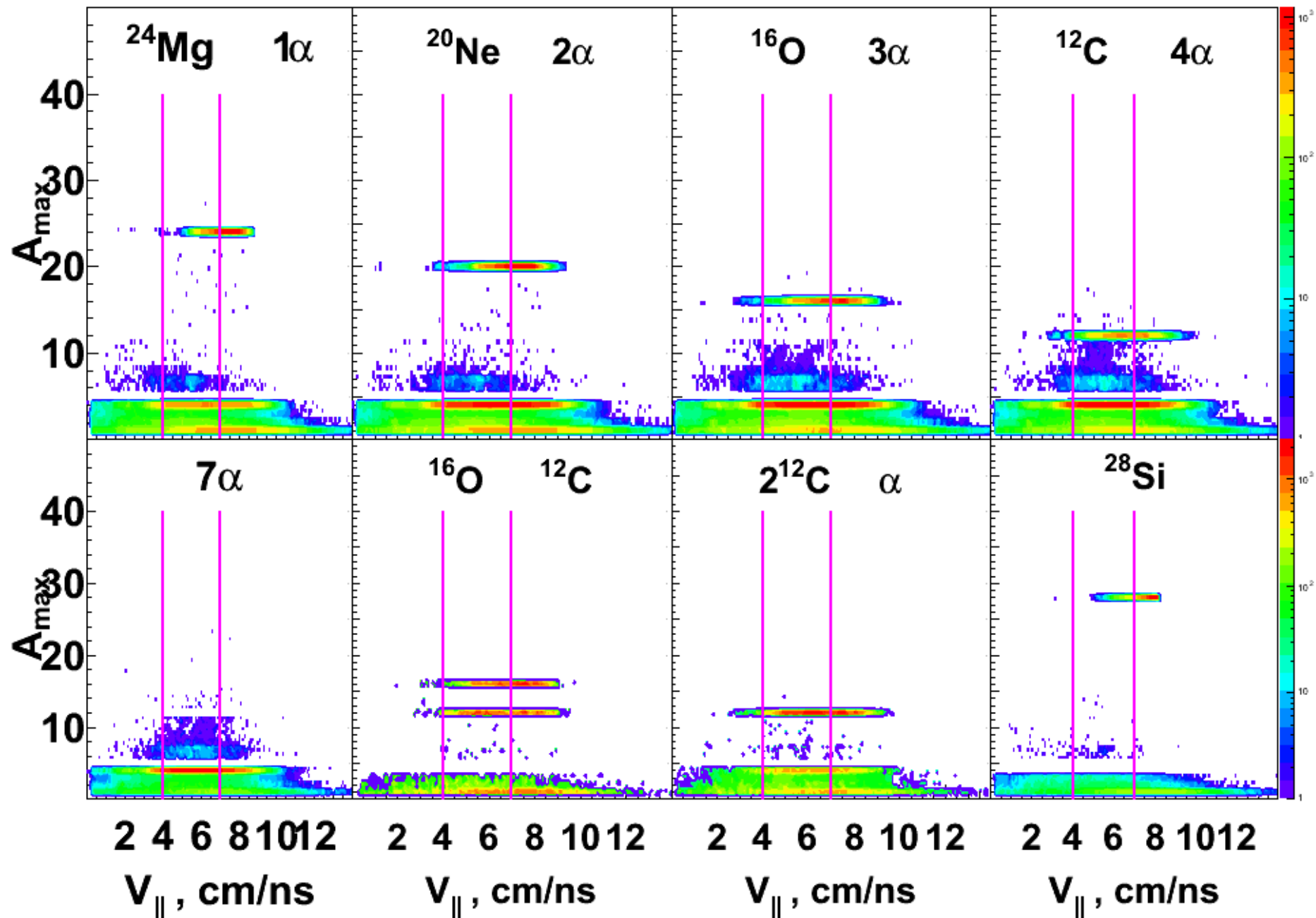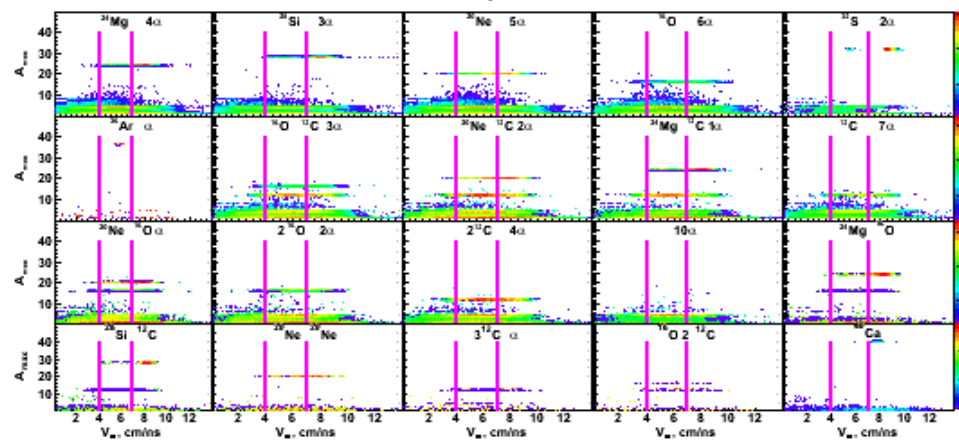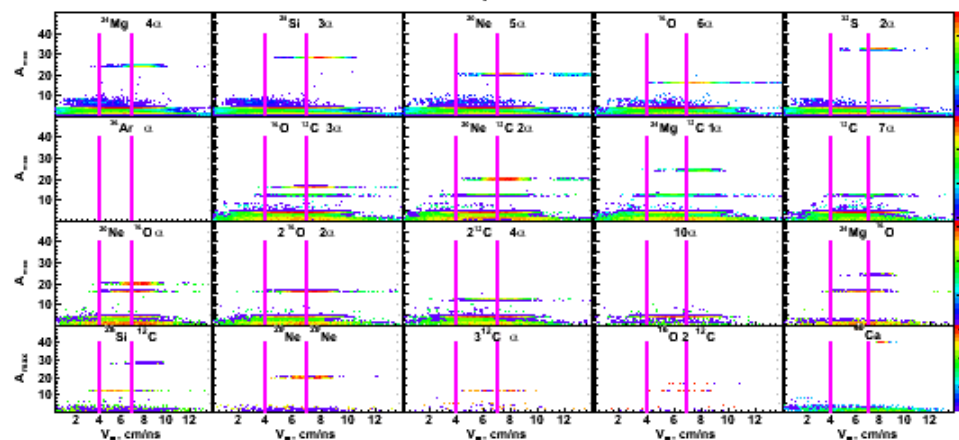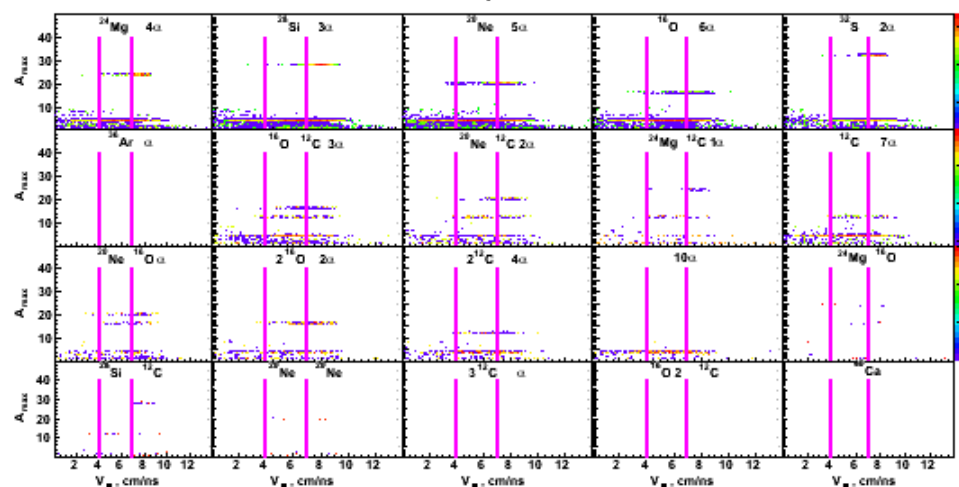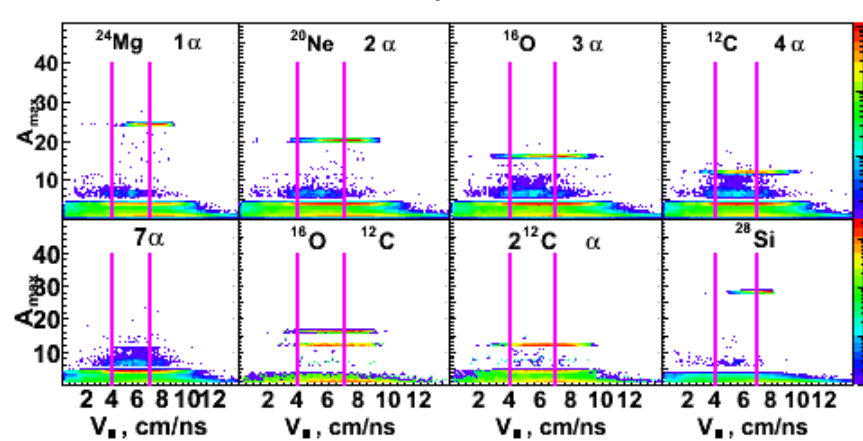
35 MeV/u Si + Si alphaLikeMass = 28

35 MeV/u Ca + C alphaLikeMass = 40

35 MeV/u Si + C alphaLikeMass = 28

35 MeV/u Ca + Ta alphaLikeMass = 40
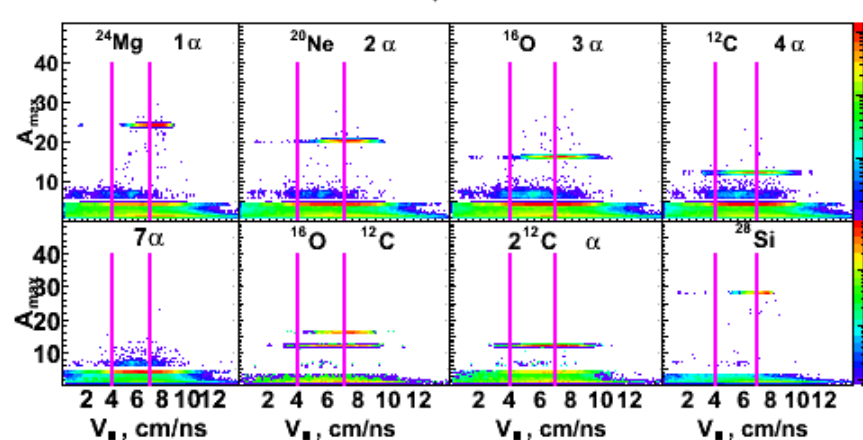
35 MeV/u Si + Ta alphaLikeMass = 28
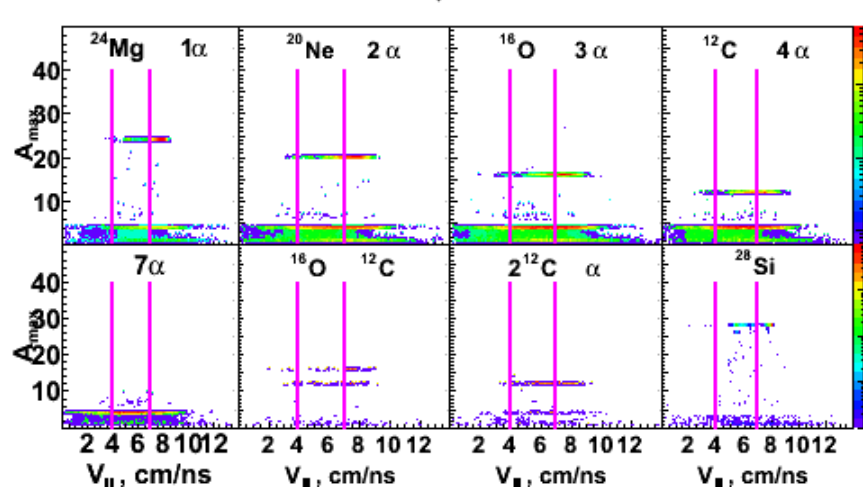
Summary

- Clusterization of alpha conjugate nuclei
- Large production of α-like nuclei in all systems studied.
- Neck emission of alphas important
  - More important in the systems with an alpha-conjugate target nucleus.
- Hierarchy Effect
  - Large fragments have higher energy than smaller fragments
  - Time ordering

Outlook and near future

- Analysis on all reaction systems continues.

  – Detectors are calibrated and the results can come quickly.

- Several other systems nearly calibrated

  – Ca + Si

  – Si + Ca

  – 25 and 10 MeV/u beam energies.

Collaborators

J. B. Natowitz, K. Schmidt, K. Hagel, R. Wada,
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V. Rizzi, G. Viesti, M. Cinausero, G. Prete, T. Keutgen,
Y. El Masri, Z. Majka, and Y. G. Ma